General publications

SUPPLY AND REQUIREMENTS PROJECTIONS OF PHYSICISTS CANADA 1976

CA1 MI 15
-71S76

3 1761 11767380 6

by
Peter Ross

LIBRARY
OCT 18 1971
UNIVERSITY OF TORONTO

Research Branch
Program Development Service
DEPARTMENT OF MANPOWER AND IMMIGRATION
CANADA
1971

CA1 MI 15
-71S76

SUPPLY AND REQUIREMENTS PROJECTIONS OF PHYSICISTS CANADA 1976

by
Peter Ross

RESEARCH BRANCH
PROGRAM DEVELOPMENT SERVICE
DEPARTMENT OF MANPOWER AND IMMIGRATION
CANADA 1971

Digitized by the Internet Archive
in 2023 with funding from
University of Toronto

https://archive.org/details/31761117673806

FOREWORD

This study of one component of Canada's highly qualified manpower resources is one of a series of studies in the program of research in highly qualified manpower in the Department of Manpower and Immigration. It is intended to be the first in a series of projections of the supply and demand of highly qualified manpower. It should be noted that the projections are based on a number of data and behavioural assumptions and that it is possible to derive alternative projections by changing some of these assumptions. The entire report should be read with this in mind especially if the results are to be used for planning purposes and practical decision making.

The study was carried out by Peter Ross of the Department of Manpower and Immigration. The author was assisted by Dr. R. W. Baguley of the University of Western Ontario and Dr. R. Smith of the University of Ottawa who represented the Canadian Association of Physicists. Mr. J. L. Meunier, Executive Director of the Canadian Association of Physicists provided considerable assistance in the planning. Mr. R. Knowles aided in much of the data collection.

G. Saunders,
Director,
Research Branch.

G. Neil Perry,
Assistant Deputy Minister,
Program Development Service.

INTRODUCTION

Looking ahead to 1976, if current trends continue, and of course there is no certainty that they will, there is a likelihood that the Canadian economy will have more physicists seeking employment as professional physicists than the market may be able to absorb. That is the message of this study. But much can happen between now and 1976 to affect both the demand and the supply outlook; the message, therefore, can only have a short span of validity.

Our purpose in publishing the results of this study is to alert all the interested parties to the consequences of the present tendencies and to learn with experience how to improve both the methodology and, naturally, the utility of studies in this field.

It is hoped that a periodic updating of the projections can be implemented so that the effect of annual events such as enrolments on the projected market situation can be quickly ascertained.

TABLE OF CONTENTS

CHAPTER 1

THE STOCK OF CANADIAN PHYSICISTS

1.1 Data on the Stock of Physicists

There are four major sources of data on the stock of physicists: (1) the 1961 Census; (2) the 1962 Department of Labour Survey; (3) the 1965 Department of Labour Canadian Association of Physicists (CAP) Survey; (4) the 1967 Survey of Highly Qualified Manpower of the Department of Manpower and Immigration. Major reference will be made to the latter two surveys. Also, some reference will be made to DBS data.

This study does not provide a detailed analysis and comparison of the above-mentioned data. Such material may be the subject of a forthcoming publication of the Department. The establishment of a projection base and the presentation of supply and requirements projections of physicists to 1976 are the concerns of this study.

1.2 The Census, 1961

Although the Department of Manpower and Immigration is currently preparing consistent occupation-by-industry matrices for the census years 1941, 1951 and 1961, physicists appear for the first time in the 1961 Census.

According to the census, 699 physicists were enumerated in 1961. The category "physical scientists, not elsewhere specified" consists of 28 functional titles clustered mainly around geophysics, metorology, seismology and astronomy. If this category is included with "physicists", Canada's 1961 stock of physicists totalled 2,114.

Acceptance of the census occupational total implies that some "highly qualified professionals" have only a limited amount of professional education since, in the census, a person who performs a certain type of work is tabulated in the appropriate occupational category. Thus, a person working in an engineering department might pass for an engineer although he is a draftsman by training.

1.3 The Department of Labour Survey, 1961

Seven months after the 1961 Census, the Department of Labour conducted a survey of engineering and scientific manpower based mainly on a professional training concept. This survey provides a second major observation on the stock and employment characteristics of Canadian physicists.

According to the survey, Canada had 1,089 physicists and 562 mathematicians and physicists.

The enumeration is incomplete since the survey was limited to establishments of more than 100 employees. Since the survey underestimates the number of physicists, it appears reasonable to include the 1961 Census enumeration of "physical scientists, not elsewhere specified", as comprising part of Canada's 1961 stock of physicists.

1.4 The Department of Labour Canadian Association of Physicists Survey, 1965

In 1965, the Department of Labour and the Canadian Association of Physicists conducted a survey of Canadian physicists. The 1964 stock of Canadian physicists is divided by field of specialization into 13 main subfields and 10 allied subfields - a somewhat arbitrary division based largely on the fact that the only data for the main subfields in comparable with that gathered for the United States physics community by the American Institute of Physics (AIP) in 1962. According to the survey, Canada's 1964 stock of physicists numbered 1,886 with 1,341 in the main subfields and 545 in the allied subfields. The field breakdown is presented in Table 1.1.

Table 1.1

Classification of Canadian Physicists by Main and Allied Subfields of Specialization

Main Subfields	Number	Per Cent	Allied Subfields	Number	Per Cent
Acoustics	63	4.7	Atmospheric Dynamics Chemistry and Physics	58	10.6
Astronomy	49	3.7	Climatology	10	1.8
Atomic and Molecular	87	6.5	Synoptic Meteorology	145	26.6
Electromagnetism	84	6.3	Meteorological Instrumentation	11	2.0
Electronics	95	7.1	Solid-earth Geophysics	79	14.5
Elementary Particles	32	2.4	Oceanography	33	6.1
Mechanics	28	2.1	Maths of Resource Use	43	7.9
Nuclear	201	15.0	Numerical Methods and Computation	102	18.7
Optics	79	5.9	Physical Chemistry	13	2.4
Fluids	63	4.7	Biophysics	51	9.4
Solid State	164	12.2			
Thermal	43	3.2			
Other	353	26.3			
TOTALS	1,341	100.0	TOTALS	545	100.0

Source: Physics in Canada, Vol. 21, No. 3. Tables 2.2 and 2.3, pp. 24 and 25.

The overall response rate to the survey was approximately 77 per cent. It is highly likely that the response rate for the main subfields is higher than for the allied subfields since 40 per cent of physicists in the main subfields are CAP members while only 27 per cent of the allied subfields are members.

To estimate the total number of physicists it was decided to break the overall response rate of 77 per cent into 88.14 per cent for the main subfields and 58.76 per cent for the allied subfields, as the CAP membership in the main subfields is approximately $1\frac{1}{2}$ times the CAP membership in the allied subfields. Adjustment by response rate yields 1,521 (1,341/.8814) physicists in the main subfields and 928 (545/.5876) in the allied subfields - a total of 2,449.

1.5 The Department of Manpower and Immigration Survey, 1967

The 1967 Survey of Scientific, Professional and Technical Manpower conducted by the Department of Manpower and Immigration included physicists as one of the occupational subdivisions.

In selecting the physicists from all the respondents to the 1967 survey, the basic criteria were: (1) anyone who has a degree in physics; and (2) anyone whose work activity in 1966 was classified as physics (specialties 0800 to 0979 and 2666 to 2675 in the Department of Manpower and Immigration's "Major Fields and Specialties List") or related to physics. The above specialties are presented in Table 1.2 below.

Table 1.2

1967 Survey Specialties

PHYSICS

Acoustics

0800-Applied acoustics, instruments and apparatus
0801-Architectural acoustics
0802-Ear and hearing
0803-Electroacoustics
0804-Infrasonics
0805-Mechanical vibrations and shock
0806-Musical instruments and music
0807-Noise
0808-Speech communications
0809-Theory of waves and vibrations
0810-Ultrasonics
0811-Underwater sound
0812-Other (specify)

Atomic and Molecular Physics

0813-Atomic, ionic and molecular beams
0814-Atomic masses and abundance
0815-Atomic structure and spectra
0816-Chemical bonds and structure
0817-Electron paramagnetic resonance
0818-Impact and scattering phenomena
0819-Mass spectroscopy
0820-Molecular structure and spectra
0821-Nuclear magnetic resonance
0822-Other (specify)

Electromagnetism

0823-Antenna theory
0824-Electrical measurements and instruments
0825-Electromagnetic waves
0826-Electromagnetic wave propagation
0827-Electron dynamics
0828-Electron microscopy, ionoptics
0829-Gas discharge
0830-Magnetism
0831-Masers and such devices
0832-Microwaves
0833-Physical electronics
0834-Quantum electronics
0835-X-ray interactions
0836-X-ray phenomena
0837-X-ray technology
0838-Other (specify)

Elementary Particles

0839-Cosmic rays
0840-High energy accelerators
0841-High energy phenomena
0842-Particle detectors
0843-Phenomenological computer analysis
0844-Other (specify)

Mechanics

0845-Analytical mechanics
0846-Ballistics and flight dynamics
0847-Elasticity
0848-Friction
0849-High pressure physics
0850-Impact phenomena
0851-Instruments and measurements
0852-Other (specify)

Nuclear Physics

0853-Accelerators, detectors
0854-Neutrons
0855-Nuclear properties
0856-Nuclear reactions and scattering
0857-Nuclear spectroscopy
0858-Radiation effects
0859-Radioactive materials, isotopes
0860-Reactors
0861-Shielding
0862-Other (specify)

Optics

0863-Atmospheric and space optics
0864-Color, colorimetry
0865-Fiber optics
0866-Geometrical optics
0867-Information theory, communications, image evaluation
0868-Infrared phenomena
0869-Interferometry
0870-Lasers
0871-Lenses
0872-Optical instruments, techniques and devices
0873-Optical materials
0874-Photography, illumination
0875-Physical optics
0876-Physiological optics
0877-Properties of thin films
0878-Radiometry, photometry
0879-Spectroscopy
0880-Other (specify)

Physics of Fluids

0881-Aerodynamics
0882-Aerosols
0883-Boundary layer effects
0884-Cavities and jets
0885-Compressible fluid dynamics
0886-Explosion phenomena
0887-High temperature flow
0888-Incompressible fluid dynamics
0889-Magneto fluid dynamics
0890-Plasma physics
0891-Rarefied gas flow
0892-Rheology (including plastic flow)
0893-Shock wave phenomena
0894-Structure and properties of fluids
0895-Superfluidity
0896-Transport phenomena, diffusion
0897-Turbulence
0898-Viscosity
0899-Other (specify)

Solid State Physics

0900-Ceramics
0901-Cooperative phenomena
0902-Crystallography
0903-Dielectrics (including fluids)
0904-Dislocations and plasticity
0905-Dynamics of crystal lattices
0906-Electrical properties of surfaces and junctions
0907-Electron emission
0908-Ferromagnetism
0909-High polymers and glasses
0910-Internal friction
0911-Lattice effects and diffusion
0912-Luminescence
0913-Optical properties
0914-Para- and diamagnetism phenomena
0915-Photoconductivity and related phenomena
0916-Photoelectric phenomena

Solid State
Physics (Cont'd.)

0917-Piezo and ferro-electricity
0918-Quantum mechanics of solids
0919-Radiation damage
0920-Resonance phenomena
0921-Semiconductors
0922-Superconductivity
0923-Surface structure and kinetics
0924-Thermal conduction in solid state
0925-Thin films
0926-Other (specify)

Thermal Physics

0927-Calorimetry
0928-Heat transmission
0929-High temperature physics
0930-Low temperature physics
0931-Temperature and its measurement
0932-Thermal properties
0933-Thermodynamics
0934-Thermodynamic relations, equations of state
0935-Thermodynamic tables
0936-Other (specify)

Other Physics
Specialties

0937-Constants, standards, units, metrology, conversion factors
0938-Energy conversion problems
0939-Field theory
0940-High vacuum techniques
0941-Magnetohydrodynamics
0942-Many body theory
0943-Mathematical physics
0944-Mossbauer effect
0945-Physical metallurgy
0946-Physical properties of materials
0947-Quantum mechanics
0948-Radiation and health physics
0949-Relativity and gravitation
0950-Statistical mechanics and kinetic theory
0951-Physics, other (specify)

ASTRONOMY

0960-Astrometry
0961-Astrophysics
0962-Celestial mechanics
0963-Comets, meteors, interplanetary medium
0964-Cosmology and cosmogony
0965-Design of astronomical instruments
0966-Galaxies
0967-Navigation, geodetic astronomy
0968-Origin of cosmic rays
0969-Photometry of astronomical sources
0970-Physics of the interstellar medium
0971-Planets, satellites
0972-Radio astronomy
0973-Space astronomy
0974-Spectroscopy of astronomical sources
0975-Star systems and statistical astronomy
0976-Stellar energy generation, nucleogenesis, stellar evolution
0977-The sun
0978-Variable stars
0979-Other (specify)

Electronics

2666-Electron ballistics
2667-Electron tubes
2668-Electronic device circuitry
2669-Electronics instrumentation
2670-Emission
2671-Gas devices
2672-Gaseous electronics
2673-Semiconductor devices
2674-Solid state electronics
2675-Other (specify)

The field breakdown is presented in Table 1.3. According to this survey, there were 1,074 physicists in the main subfields and 1,174 physicists in the allied subfields in 1966. These figures are not adjusted for the response rate. The overall response rate for physicists was 92 per cent. Application of this response rate yields 1,167 physicists in the main subfields and 1,276 physicists in the allied subfields. It was decided not to differentially weigh the response rates by main and allied subfields as it is believed that the 1967 survey covered the allied subfields to a far greater extent than the 1965 Department of Labour Survey - CAP Survey. The 1967 survey was less inclusive when it came to enumerating those physicists in the main subfields (especially those in the university community) as will be seen in the next section.

Table 1.3

Classification of Canadian Physicists by
Main and Allied Subfields of Specialization

Main Subfields	Number	Per Cent	Allied Subfields	Number	Per Cent
Acoustics	47	4.4	Atmospheric Dynamics, Chemistry and Physics	57	4.9
Astronomy	66	6.1			
Atomic and Molecular	73	6.8			
Electromagnetism	77	7.2	Climatology	19	1.6
Electronics	66	6.1	Synoptic Meteorology	235	20.0
Elementary Particles	22	2.0	Meteorological Instrumentation	3	.3
Mechanics	42	3.9	Solid-earth Geophysics	89	7.6
Nuclear	176	16.4			
Optics	57	5.3	Oceanography	59	5.0
Fluids	43	4.0	Maths of Resource Use	236	20.1
Solid State	135	12.6	Numerical Methods and Computation	304	25.9
Thermal	34	3.2			
Other	236	22.0	Physical Chemistry	159	13.5
			Biophysics	13	1.1
TOTALS	1,074	100.0	TOTALS	1,174	100.0

Source: 1967 Survey.

1.6 Reconciliation of Surveys and Enumerations and Final Estimates of the Stock of Physicists

The varying stocks of physicists as reported by the three surveys and the 1961 Census must be reconciled in order to obtain reasonable estimates of the stock of physicists so that supply and requirements projections can be carried out.

The four surveys dealing with the stock of physicists to date yield the following results adjusted for response rate as presented in Table 1.4.

Table 1.4

Summary of Surveys

	Main Subfields	Allied Subfields	Total
(1) Census (1961) for 1961	699	1,415	2,114
(2) Department of Labour (1962) for 1961	1,089	562	1,651
(3) Department of Labour - CAP (1965) for 1964	1,521	928	2,449
(4) Department of Manpower and Immigration (1967) for 1966	1,167	1,276	2,443

The first two can be used to obtain a stock estimate for 1961 and the last two can be used to obtain a stock estimate for 1966.

With reference to (1) and (2) the column averages are 894, 989 and 1,883 respectively. The figure 1,900 appears appropriate for the total as the census classification is occupational and thus overestimates and the Department of Labour survey underestimates as it did not cover smaller establishments. The 1,900 should be broken into 900 for the main subfields and 1,000 for the allied subfields - this follows from rounding to the nearest hundred and because the 1967 survey and U.S. data indicate that the allied subfields are approximately 52 per cent of the total.

To obtain a stock estimate for 1966, it was decided to settle on 2,500 because of the difficulties in reconciling the 1965 and 1967 survey results. Also relevant is the fact that the increase from 1,900 to 2,500 over the five years represents a compound growth rate of approximately $5\frac{1}{2}$ per cent per annum. Given that the U.S. growth rate was approximately $4\frac{1}{2}$ per cent per annum between the period 1962-1968, 2,500 seems appropriate for the 1966 stock of physicists.

The figure 2,500 should be broken into 1,200 for the main subfields and 1,300 for the allied subfields to maintain the approximately 48:52 ratio.

In summary, the stocks of physicists for 1961 and 1966 that will be used throughout the rest of this report are presented in Table 1.5.

Table 1.5

Final Stock Estimates

	Main Subfields	Allied Subfields	Total
1961	900	1,000	1,900
1966	1,200	1,300	2,500

CHAPTER 2

PROJECTIONS OF 1976 REQUIREMENTS FOR PHYSICISTS

2.1 Methodological Issues

Extrapolation of past trends in employment into the future is a popular procedure for projecting target year manpower requirements. The most serious theoretical disadvantage of the procedure is its implication that the same complex of causative factors that have determined employment in a specific occupation in a particular industry or economic sector in the past will continue to operate in an identical manner in the future. This implicit assumption becomes particularly tenuous when one is interested in projecting requirements for highly qualified manpower where unforeseen technological developments and other micro-economic considerations are especially important in determining demand. These factors become increasingly important if we are interested in projecting requirements for specialists in certain subfields of a highly qualified occupation category which may alter the specialization mix without necessarily altering the aggregate. Thus, the development of the laser in the United States led to increased demand for physicists specializing in optics and the recent development of an atmospheric pressure carbon dioxide gas laser in Canada may be expected to similarly increase the proportion of Canadian physicists in this subfield.

As an illustration of the extrapolation procedure, one could project 1976 requirements for physicists by projecting for each economic sector:

(a) employment of physicists as a proportion of total employment,

(b) total employment as a proportion of output,

(c) output.

Multiplication of the three estimates gives 1976 requirements for physicists in each sector. Summing overall sectors yields an estimate of national requirements for physicists in the target year. This procedure has been used to estimate requirements for broadly defined occupational categories in highly aggregated sectors of the economy such as manufacturing, agriculture, trade, service, etc., industries.[1] Trends were obtained from occupation-by-industry matrices for the three census years of 1941, 1951, and 1961. The above procedure is not applied to any great extent in this case as for physicists, there does not exist an adequate time series on the necessary variables.

---

(1) B. Ahamad. A Projection of Manpower Requirements by Occupation in 1975, Research Branch, Program Development Service, Department of Manpower and Immigration, 1969.

2.2 Occupational Distribution of Physicists

The projections of 1976 requirements for physicists are based largely upon the employment distribution of Canadian physicists. Difficulties arise with the employment distribution as there appears to be differences between the distributions found using the Department of Labour - CAP data and the 1967 survey data.

The employment distributions as found in the two surveys are presented in Tables 2.1 and 2.2.

Table 2.1

Employment Distribution of Physicists - 1967 Survey

Employer	Main Subfields		Allied Subfields		Total	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Government	279	26.0	429	36.5	708	31.7
Education	446	41.5	204	17.5	650	29.2
Industry	349	32.5	541	46.0	890	39.1
	1,074	100.0	1,174	100.0	2,248	100.0

Table 2.2

Employment Distribution of Physicists -
Department of Labour - CAP Survey

Employer	Main Subfields		Allied Subfields		Total	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Government	271	20.2	287	52.7	558	29.6
Education	759	56.6	111	20.4	870	46.1
Industry	311	23.2	147	26.9	458	24.3
	1,341	100.0	545	100.0	1,886	100.0

As indicated earlier, the 1967 survey did not completely enumerate the university community and the Department of Labour - CAP survey did not completely enumerate the allied subfields. In order to arrive at a single employment distribution, it was decided to use the best estimates of both surveys. Accordingly, the 1967 survey percentages are used for the allied subfields and the Department of Labour - CAP percentages are used for the main subfields. The joint percentage distribution is presented below in Table 2.3.

Table 2.3

Joint Percentage Employment Distribution of Physicists

Employer	Main Subfields	Allied Subfields
Government	20.2	36.5
Education	56.6	17.5
Industry	23.2	46.0
	100.0	100.0

Application of the above distribution to the total stock of physicists in 1966 arrived at in Chapter 1 (1,200 in the main subfields and 1,300 in the allied subfields) yields the distribution as presented in Table 2.4 following.

Table 2.4

Joint Employment Distribution of Physicists - 1966

Employer	Main Subfields		Allied Subfields		Total	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Government	243	20.2	475	36.5	718	28.7
Education	679	56.6	227	17.5	906	36.2
Manufacturing	278	23.2	598	46.0	876	35.1
	1,200	100.0	1,300	100.0	2,500	100.0

The above distribution will serve as the basis for requirements projections by sector of employment.

2.3(a) Projected Requirements for All Physicists in Canadian Manufacturing

This section projects 1976 requirements for physicists in Canadian manufacturing where the term manufacturing includes all employment except employment in government or education (colleges and universities).

The basic premise is that the demand for any factor of production can be derived from the demand for the goods and services that it helps to produce. To project manpower requirements at the industrial level involves projecting the output of each industry in the economy.

One method of projecting the output of each industry in the economy would be to project total final demand or Gross National Product in the target year and then allocate this demand among all industries in the economy. This procedure would be extremely time-consuming and expensive. At a minimum, it would involve an analysis of trends in consumption, investment, government and foreign expenditures relative to total expenditures over time, and of trends in consumption and other expenditures on different commodities over time. The simplifying assumption made here is that final demands distributed among industries in the same proportion as they were in the most recent year for which industry relationships are calculated. This implies that the share of income going to major expenditure groups and that the pattern of tastes for different commodities by these groups will remain unchanged between the base year and the target year. Therefore, the growth rate of any particular industry's output will be equal to the growth rate of aggregate demand or GNP.

In 1963, the Economic Council of Canada set a goal of 5.5 per cent growth for output - 2.5 per cent for productivity growth and 3.0 per cent for employment growth - for the period 1963-1970. Actual performance between 1946 and 1967 clearly falls short of this goal, but the data for the longer period reflect the conditions prevailing in the late 1950's and early 1960's when unemployment reached post-war record levels and there was virtually no growth in real incomes. In the more recent period, 1961-1968, real output grew at an average annual rate of 5.55 per cent. This growth rate reflected an increase in employment by 3.2 per cent per year and productivity increases of 2.35 per cent per year.(1) Between 1963 and 1968, real output again grew by 5.5 per cent per year reflecting a 3.4 per cent annual increase in employment and a 2.15 per cent increase in productivity. These figures suggest that the goal of the Economic Council will be met, but growth in employment appears to be playing a larger role and growth in productivity a smaller role than the council envisaged.

For the purpose of these projections, it is assumed that income will grow by 5.5 per cent per year over the projection period. This appears to be the most realistic assumption although numerous alternatives are available. The growth rate of manpower requirements in any economic sector can then be estimated as the difference between the growth rate of national production and productivity growth in the sector being considered.

---

(1) This and any other statistical information which is not explicitly footnoted is based on DBS, Canadian Statistical Review, various issues and DBS, National Accounts, Income and Expenditure, various issues.

The Dominion Bureau of Statistics constructs a series of productivity indices for various sectors of the economy. Productivity in the commercial industries (which includes all industries except public administration, defence, and non-profit institutions such as hospitals and educational institutions) increased 3.5 per cent per year between 1946 and 1967. This high rate partially reflects the fact that agriculture shows the greatest increase in output per man of all economic sectors. If agricultural industries are excluded, the average rate of productivity growth falls to 2.8 per cent per year over the period. In recent years, productivity gains have been much lower in each of the four groupings noted above. The relevant information is best summarized in Table 2.5. In the projections which follow, it is assumed that productivity in each sector will grow at the same rate between 1967 and 1976 as it did between 1963 and 1967. The use of these figures assumes that the underlying economic conditions which determine productivity growth will be the same over the next few years as they were in the recent past when the economy was operating fairly close to its potential. The reader can easily adjust the resulting projections in the light of emerging evidence concerning future productivity trends. Finally, in order to project requirements for physicists from projections of total manpower requirements, it is assumed for the present that the employment of physicists in any economic sector is a constant proportion of total employment in that sector.

Table 2.5

Average Annual Rate of Productivity Growth

Time Period	Commercial Industries	Non-Agricultural Commercial Industries	Manufacturing Industries	Non-Manufacturing Industries
1946-1947	3.50	2.80	3.70	2.30
1961-1967	2.95	2.20	3.80	1.50
1963-1967	2.30	1.90	2.80	1.40

Source: Dominion Bureau of Statistics. Aggregate Productivity Trends, 1946-1967. Cat. No. 14-201.

The most appropriate productivity growth rate is 2.8 per cent (manufacturing industries) as the majority of physicists are employed in manufacturing industries. Given a growth rate of GNP of 5.5 per cent and a productivity growth rate of 2.8 per cent yields a 2.7 per cent (5.5 per cent - 2.8 per cent) growth in requirements for physicists.

Application of the 2.7 per cent growth to the 278 physicists in the main subfields and 598 physicists in the allied subfields in 1976 yields the following:

Table 2.6

Projected Requirements for Physicists in Industry - 1976

Main Subfields	Allied Subfields	Total
363	781	1,144

2.3(b) Projected Requirements for Research Physicists in Canadian Industry

A large percentage of physicists in industry are employed in research. DBS data on research physicists in Canadian industry is portrayed in Table 2.7 below.

Table 2.7

Research Physicists Employed by Industry Group: 1957-1965

Industry Group	1957	1959	1961	1963	1965
Manufacturing					
Food and Beverages	1	1	3	1	-
Rubber	1	1	1	2	2
Textiles	4	17	1	1	2
Wood	-	-	-	-	-
Furniture and Fixtures	-	-	-	-	-
Paper	17	18	6	12	12
Primary Metals (ferrous)	-	-	(27)	(16)	-
Primary Metals (non-ferrous)	21	26	-	-	-
Metal Fabricating	-	-	-	5	6
Machinery	-	-	1	3	-
Transportation Equipment	52	27	3	16	15
Electrical Products	49	58	51	88	118
Non-Metallic Mineral Products	2	1	5	9	10
Petroleum Products	8	8	5	1	4

Table 2.7

Research Physicists Employed by
Industry Group: 1957-1965 (Cont'd.)

Industry Group	1957	1959	1961	1963	1965
Manufacturing (Cont'd.)					
Chemical Products	17	17	25	22	24
Scientific and Professional Instruments	-	-	-	-	23
Other Manufacturing	1	15	5	30	3
Total Manufacturing	173	179	133	206	230
Mining, Quarrying and Oilwells	6	28	7	6	1
Transportation and Other Utilities	2	1	1	1	2
Other Non-Manufacturing	4	4	3	7	3
Total Non-Manufacturing	12	33	11	14	6
Total Industry	185	212	144	220	236

Note: Figures published every two years.

Sources: 1957: DBS Cat. No. 13-509, Table 11.
1959: DBS Cat. No. 13-516, Table 11.
1961: DBS Cat. No. 13-520, Table 10.
1963: DBS Cat. No. 13-524, Table 14.
1965: DBS Cat. No. 13-527, Table 27.

One would expect the employment of research personnel to be more closely related to research and development expenditures than to output per se. The projection in 2.3 was based on output.

The purpose of this section is to examine the projections of research and development expenditures. The following tables give employment in and expenditure on research for selected years between 1955 and 1965.

Table 2.8

Research and Development Personnel in Industry

Year	Physicists	Total	Ratio
1955	143	2,914	.049
1957	185	4,448	.042
1959	212	4,141	.051
1961	144	4,673	.031
1963	220	5,795	.038
1965	236	6,367	.037

Sources: 1955: Industrial Research-Development Expenditures in Canada. DBS, Table 9.
1957: DBS, 13-509, Table 11.
1959: DBS, 13-516, Tables 10 and 11, p. 26.
1961: DBS, 13-520, Tables 9 and 10.
1963: DBS, 13-524, Table 14.
1965: DBS, Tables 26 and 27, p. 38.

Table 2.9

Total Research-Development Expenditures in Industry by Field of Research

Year	Field of Research: Physics $000's	Field of Research: Total $000's	Ratio
1955	3,067	65,886	.047
1957	10,135	149,144	.068
1959	4,193	96,690	.043
1961	3,410	113,255	.030
1963	5,251	160,171	.033
1965	9,427	235,009	.040

Sources: 1955: DBS, Reference Paper No. 74, Table 4.
1957: DBS, 13-509, Table 4.
1959: DBS, 13-516, Table 6.
1961: DBS, 13-520, Table 5.
1963: DBS, 13-524, Table 8.
1965: DBS, 13-527, Table 12.

A statistically significant relationship between total R and D employment and total R and D expenditures was given by the equation

$$N = 2,100.8 + .01913\ E$$

where

N = number of people employed and
E = expenditures in thousands of dollars

The equation relating employment of physicists to R and D expenditures for physicists is

$$P = 149.7 + .00679\ PE$$

where

P = physicists and
PE = expenditures on physics in thousands of dollars

but is statistically insignificant and therefore will not be utilized.

The first (significant) relation was used to project 1976 requirements for physicists by making assumptions regarding:

(1) the ratio of physicists to total R and D personnel in 1976; and

(2) the volume of industrial R and D expenditures in 1976.

A slight downward trend in the ratio of physicists to total R and D personnel is apparent in the figures presented in Table 2.9 but for projection purposes, it is assumed that the ratio remains constant at its mean value of .0413 over the 1955-1965 period. This implies that 4.13 per cent or about one out of every 25 persons involved in industrial research and development activities in 1976 will be a physicist.

The projection of 1976 R and D expenditures is equally difficult because these expenditures are, or can be, largely policy determined.

The assumption that R and D expenditures grow at the same rate as real GNP implies that the ratio of R and D expenditures to real income remains constant at its 1965 level. This would appear to be an unreasonable assumption as R and D expenditures grew at an average annual rate of 13.5 per cent between 1955 and 1965. If that rate of growth were to prevail from 1965 to 1976 then the R and D expenditures anticipated in 1976 would represent 1.09 per cent of real GNP in 1976. The assumption of a 13.5 per cent growth rate would appear reasonable as industrial R and D expenditures in the U.S.A. comprised 2.09 per cent of U.S. GNP in 1961-1962. This figure falls to 1.03 per cent if defence expenditures are excluded. Also, there appears to be no reason to expect the growth rate of industrial expenditures from R and D to increase markedly above the level observed in the recent past. It is important to realize that the incentives for research activities in

Canadian industry can be much curtailed by the simple fact that Canadian industries can freely borrow the technological discoveries emanating from the better equipped and better financed research laboratories of the U.S. parent companies.

The growth rate of 13.5 per cent of R and D expenditures means, according to the previous assumptions that 20,204 persons will be required in research work in 1976 - 834 of these will be physicists.

The projection of 834 research physicists appears to be reasonable compared to the projection of total physicists of 1,144 in 1976 as the research physicists reported in 1965 are approximately 83 per cent of the total physicists in the main subfields reported by the 1965 Department of Labour Survey - CAP Survey.

In view of the approximate agreement between projections of research physicists and projections of total physicists, it appears that industrial requirements for physicists in 1976 will be approximately 1,144

2.4 Projected Requirements for Physicists in Canadian Universities

Requirements for physicists in Canadian universities are assumed to depend upon future enrolments and trends in the student-faculty ratio.

2.4(a) University Enrolment

Zsigmond and Wenaas in Enrolment in Educational Institutions by Province, 1951-1952 to 1980-1981 (Staff Study No. 25 for the Economic Council of Canada) project 1975-1976 enrolment at 560,000 students. The total includes those in teachers' colleges who will be included in the universities in the future. As this study is concerned with physicists, it was decided to take teacher's college enrolments out of the total of 560,000. This was done by projecting the ratio of teacher's college enrolments to total university enrolment and subtracting teacher's college enrolment from total university enrolment in 1975-1976 on the basis of the ratio. The total university enrolment in 1976 minus students in teachers' colleges is projected to be 515,310.

2.4(b) The Student-Faculty Ratio

The number of university teachers increased at an average annual rate of 7.23 per cent between 1953 and 1966, but the relatively more rapid growth in enrolments has prevented any long-run improvements in the number of faculty members per student. The student-faculty ratio has increased

irregularly from 9.77 in 1953 to 12.87 in 1966 or by 2.11 per cent per year. The best relationship between the student-faculty ratio, E/F, and time is given by the linear relation

$$E/F = 9.69 + .23\ T$$

where

$$T = 1 \text{ in } 1953$$

which implies 15.21 students per staff member in 1976 provided, of course, that the estimating equation above remains stable until 1976.

The student-faculty ratio should in theory be negatively related to the ratio of graduate students to total enrolments, G/E, since graduate students usually require closer supervision than undergraduates. An increase in income per student, Y/E, should also be associated with an increase in the faculty-student ratio provided that the supply of university teachers is reasonably elastic. These predictions are not confirmed by casual inspection of the data presented in Table 2.10 which shows positive but insignificant correlations among all three variables.

Table 2.10

Variables Affecting the Student-Faculty Ratio

Year	E/F	G/E	Y/E $
1954	9.34	.046	1,572
1955	10.55	.048	1,631
1956	10.83	.047	1,592
1957	11.21	.044	1,911
1958	11.57	.047	1,945
1959	11.58	.048	2,197
1960	11.08	.051	2,309
1961	11.67	.057	2,546
1962	12.23	.057	2,554

Sources: (1) DBS. Cat. Nos. 81-204 and 81-211. Survey of Higher Education, Parts I and II, various editions.

(2) DBS, Survey of Education Finance, 1954-1956, 1957, 1958, 1959-1960, 1961, 1962.

Since observations on all explanatory variables together are available only for the nine years shown above, the sample is too small to justify a meaningful multiple regression of the form.

$$E/F = F(G/E, Y/E, T)$$

Even if the faculty-student ratio does increase with an increase in income per student, the response is likely to take place only after a considerable lag. Given the small number of observations, however, it is impossible to determine the length of this lag.

On the basis of the above, the projected requirements for university teachers is 33,879 (total enrolment divided by the student-faculty ratio of 15.21).

2.4(c) Projected Requirements for University Physics Teachers

The data summarized in Table 2.11 below indicates that the ratio of physics teachers to total university teachers increased from .0254 in 1957 to .0326 in 1966.

Table 2.11

Physics Teachers in Canadian Colleges and Universities

	University Teachers		
Year Ended	Physics	Total	Ratio
1957	178	7,000	.0254
1958	214	7,500	.0285
1959	231	8,200	.0282
1961	291	9,755	.0298
1963	364	11,670	.0312
1964	415	12,940	.0321
1966	521	16,000	.0326

Sources: (1) DBS. Cat. No. 81-203, Tables 10-11. Figures for the separate years are not strictly comparable since a few small institutions are not included for all the years in all tables.

(2) DBS. Cat. No. 81-211, Part II, various issues.

The average annual rate of growth in the ratio is 2.8 per cent. If this ratio is maintained, the ratio of physics teachers to all university teachers will be .04296 in 1976. If a linear trend is estimated, the resultant equation is $F_p/F = .026 + .000726\ T$ where F_p represents physics teachers and T = 1 in 1957. The projected ratio in 1976 (T = 20) is therefore .0405. Taking .04 (4 per cent) as a reasonable estimate, the demand for university physics teachers in 1976 will be .04 x 33,879 = 1,355.

These projections assume that the proportion of students enrolled in physics remains constant over time - if, for example, enrolment in physics declines relative to enrolment in other disciplines, target year requirements for physics teachers will be overstated. It is also assumed that the student-faculty ratio is the same in physics departments as it is in all departments combined - if, for example, the ratio is lower in physics departments, the projections will understate 1976 requirements for physicists. Enrolment data is not available in the detail required to check the validity of these assumptions. The only information on physics enrolments per se relates to the number of Canadians studying physics in the United States. This data is presented in Table 2.12 below.

Table 2.12

Canadians Studying in the United States

	Enrolments		
Year	Physics	Total	Ratio
1955	90	4,655	.0193
1956	97	4,990	.0194
1957	96	5,379	.0178
1958	99	5,271	.0188
1959	107	5,432	.0197
1960	125	5,679	.0220
1961	120	6,058	.0198
1962	140	6,571	.0213
1963	163	7,004	.0233
1964	167	8,458	.0197
1965	193	9,253	.0209
1966	185	9,755	.0190
1967	188	12,117	.0155
1968	217	12,114	.0179

Source: Open Doors , annual publication of the Institute of International Education, New York, Table II.

The ratio of physics to total enrolments for Canadians studying abroad shows no significant trend. The average value of the series is .0196. If this relationship also holds for Canadian and foreign students studying in Canadian universities and if it remains stable over the projection period, then physics enrolments can be projected to approximately 10,866 in 1976.

A projection of the student-faculty ratios on physics departments is needed. If figures for total enrolments are multiplied by the proportion of Canadian students studying physics in U.S. universities in years where there is information on both surveys, a time series showing estimated physics enrolments in Canadian universities is obtained. From this the student-faculty ratio in Canadian physics departments can be estimated. The data is summarized below in Table 2.13.

Table 2.13

Estimated Student-Faculty Ratios in Canadian Physics Departments

Year	Estimated Physics Enrolments	Number of Physics Teachers	Estimated Student-Faculty Ratios
1957	1,397	178	7.85
1958	1,631	214	7.62
1959	1,871	231	8.10
1961	2,255	291	7.75
1963	3,294	364	9.05
1964	3,120	415	7.52
1966	3,912	521	7.51
1968	4,676	673	6.95

Source: DBS. Cat. No. 81-203, Tables 10-11.

Except for the two years 1959 and 1963, the student-faculty ratio in physics departments has declined. The average rate of decrease in the ratio is 1.1 per cent per year, which if maintained, implies a student-faculty ratio of 6.35 in 1976. If a linear trend is fitted, the equation is

$$E_p/F_p = 8.103 - .0527\ T$$

where E_p/F_p is the estimated student-faculty ratio in physics departments.

If this relationship remains stable over the projection period, the 1976 (T = 20) ratio should be 7.05. Both estimators yield the same mean absolute error, so using the projection of 10,735 physics students and a student-faculty ratio of 7.05 in 1976, requirements for physics teachers should be 10,866/7.05 $\doteq$ 1,541 Given the relative equality of the prior projection of 1,355 and the current one of 1,541 it would be appropriate to settle on the average value of 1,448 as the projected requirements for university teachers of physics in 1976.

Using the fact from the joint employment distribution (Table 2.4) that approximately 25 per cent of those in education are in the allied subfields yields a university demand in the main subfields and in the allied subfields as presented in Table 2.14 below.

Table 2.14

Projected University Requirements for Physicists in 1976

Main Subfields	Allied Subfields	Total
1,086	362	1,448

2.5 Projected Requirements for Physicists in the Canadian Government

Government employment of physicists is very largely dependent upon government expenditures on research and development projects related to physics - employment will depend upon the types of research programs pursued by particular departments and agencies which employ physicists. Research and development expenditures provide the necessary lever for projecting government requirements for R and D personnel and R and D expenditures are largely exogenous or policy determined. Actual expenditures increased by 10.9 per cent per year between fiscal years 1951-1952 and 1961-1962.(1) Between 1963-1964 and 1968-1969, current expenditures for R and D increased at an average annual rate of 17.5 per cent from \$199.5 million to \$447.7 million.(2)

There is limited information on government expenditures or research and development activities in physics alone. This, and other relevant information is summarized in Table 2.15.

(1) Expenditures on R and D increased from \$63.7 million to \$178.7 million over the time period. Report 23, Scientific Research and Development, published by the Queen's Printer for the Royal Commission on Government Organization, p. 301, Appendix 1.

(2) DBS, Weekly, Cat. No. 11-002, May 9, 1969, p. 15. These are preliminary estimates.

Table 2.15

R and D Expenditures by the Federal Government by Field of Research
Millions of Dollars

Fiscal Year	Physics*	Physical Science	Total Science
1962-1963	$25.7	$59.0	$188.9
1963-1964	27.7	66.8	219.6
1964-1965	32.2	73.9	243.0

* If astronomy, metallurgy, meteorology and oceanography are included these figures become $35.3, $38.1, and $43.6 respectively.

Source: DBS. Cat. No. 13-401, Table 7.

The information summarized above shows that over the three-year period, 1962-1965, the proportion of total R and D expenditures allocated to research in the physical sciences has been stable at 30 per cent. Physicists received 43 per cent of all research dollars allocated to the physical sciences or 13 per cent of the total.

Also, the percentage that physicists are of total physical scientists employed by the government has remained stable at 30 per cent over the 1963-1967 time period as witnessed by Table 2.16 below.

Table 2.16

Research and Development Personnel in the Federal Government

Year	Physicists	Physical Scientists	Ratio
1963	479	1,539	.31
1965	475	1,645	.29
1967	550	1,817	.30

Sources: 1963: DBS. Cat. No. 13-401, Table 8, p. 31.
1965: DBS. Cat. No. 13-401, Table 12, p. 30.
1967: DBS. Cat. No. 13-401, Table 29, p. 44.

Thus, although there are an insufficient number of observations to relate employment of physicists to R and D expenditures through regression analysis, the stability of the ratios does provide a means for projecting requirements for physicists on the basis of R and D expenditures. If R and D expenditures per physicist are constant, the employment of physicists

should grow at the same rate as expenditures. As noted above, government expenditures on R and D increased at an average annual rate of 10.9 per cent between 1951 and 1962. If this rate were maintained, government requirements for physicists in the main subfields will be 684 in 1976 and 1,337 in the allied subfields in 1976 - a total of 2,021 in 1976. The projections are shown in Table 2.17 below.

Table 2.17

Projected Requirements for Physicists in Government - 1976

Main Subfields	Allied Subfields	Total
684	1,337	2,021

The assumption of a 10.9 per cent annual growth rate in R and D expenditures requires careful consideration. As indicated above, in the recent period, 1963-1969, R and D expenditures increased by 17.5 per cent per year. Between 1963 and 1969, R and D expenditures by the National Research Council increased from $42.2 to $119.4 million - an average annual rate of increase of 23 per cent.(1) This figure is especially relevant since most of the physicists employed by the federal government are employed by the National Research Council.

On the other hand, it is likely that expenditure per physicist will rise whereas for the projection, it has been assumed to remain constant so that a 10.9 per cent rate of growth is probably not a lower limit with this in mind especially if one also considers the present state of the economy.

2.6 Summary and Interpretation of the Requirements for Physicists

The requirements for physicists in 1976 on the basis of the projections presented in this chapter are presented in Table 2.18.

Table 2.18

Projected Requirements for Physicists in Canada - 1976

	Main Subfields	Allied Subfields	Total
Industry	363	781	1,144
Government	684	1,337	2,021
University	1,086	362	1,448
TOTAL	2,133	2,480	4,613

(1) DBS, Weekly Bulletin. Cat. No. 11-002, May 9, 1969, p. 16.

There are two possible major sources of error in the requirements projections: (1) the data on stocks may not be entirely accurate; (2) the assumptions about the growth rates of certain variables, e.g., gross national product, productivity, enrolment, student-faculty ratios, government expenditures, R and D expenditures, etc., may not turn out to be the rates actually observed.

Chapter 1 concerned itself, because of conflicting data, with reconciling alternative stock estimates. It may be that the reconciliation procedure does not yield the exact results although the approach to the task appears reasonable. If alternative stock estimation procedures are considered superior, there is enough background detail given to permit the manufacture of other stock estimates. Chapter 2 concerned itself with distributing the stock over various sectors of the economy. Again, the approach appears reasonable but enough detail is provided to permit alternative distributions to be derived.

With reference to (2) above, which concerns itself with assumptions regarding the future behaviour of variables, there exists possibly the greatest source of error. Many alternative assumptions could have been made about the growth rates of certain variables and a menu of demand projections could have been offered. It was felt that this should not be done as there are in some sense, "best" assumptions. In the future, if it becomes obvious because of the behaviour of certain variables that the "best" assumptions have not been chosen, these results can easily be revised to take cognizance of the changed set of circumstances.

CHAPTER 3

PROJECTIONS OF 1976 SUPPLY OF PHYSICISTS

3.1 Methodology

Given the appropriate historical data, the projection of the supply in a particular discipline is a fairly straightforward procedure. The following equation indicates the calculations necessary to obtain a projected supply figure which represents the stock in the projection year.

$$S = Sb + b + m + d + i - e - r - o$$

where

S = projected supply (stock)
Sb = stock in the last year before the projection period
b = projected number of bachelor's degrees in the discipline which enter the labour market, i.e., do not go on to graduate work
m = projected number of master's degrees in the discipline which enter the labour market, i.e., do not go on to further graduate work
d = projected doctoral degrees which enter the labour market
i = projected immigrants in the discipline
e = projected emigrants in the discipline
r = retirements and deaths over the projection period
o = those who left the discipline for other fields of employment minus those who entered from other fields of employment

3.2 Data

The data necessary for supply projections has some gaps and that which exists is to a great extent not directly comparable for analysis. In spite of the data difficulties, it was felt that a supply projection should be undertaken in order to ascertain the relative magnitude involved and also to point out the urgent need for more data. The data on enrolment and degrees were taken from the DBS catalogues 81-204 and 81-211 and the NRC publication Graduate Students in Science and Engineering at Canadian Universities (various editions).

3.3 Degree Projections

The degree projections will be presented in the order outlined by the projected supply equation.

3.3(a) Base Year Stock

In Chapter 1, a reconciliation of various surveys was undertaken in order to obtain a one number estimate of the stock of physicists which appeared reasonable in light of the conflicting survey results. For the year 1966, the total number of physicists was estimated to be 2,500-1,200 in the main subfields and 1,300 in the allied subfields. The 2,500 will be used as the base year stock for the projections to 1976. The 1961 stock estimate of 1,900 physicists will also be utilized when considering occupational mobility.

3.3(b) Bachelor's Degrees

As pointed out in Chapter 2, projections of total university enrolment to 1976 are available but enrolment in physics is not.

The only estimate of the number of physics students that can be obtained is based on the assumption that the ratio of physics students to total students is the same for students in Canada as it is for Canadian students in the U.S.A. The ratio in the U.S.A. is presented below in Table 3.1 and is assumed to stay constant at its average value of .0196 over the projection period.

To obtain the number of physics students in Canada for the period 1954-1955 to 1967-1968, the U.S.A. ratio was applied to the total number of Canadian students excluding those in the teachers' colleges.

To purge the enrolment projections of teachers' colleges enrolment, the ratio of teachers' colleges enrolment from 1956-1957 to 1967-1968 was projected to 1981 and the estimated teacher's college enrolment was subtracted from the total enrolment projections of Zsigmond and Wenaas.

The estimated number of physics students on the basis of the above calculations is presented below.

Table 3.1

Total Physics Students in Canada

Year	Total Enrolment Excluding Teachers' Colleges	Ratio of Canadian Physics Students in U.S.A. to Total Canadian Students in U.S.A.	Total Physics Students
	(1)	(2)	(3) = (1) X (2)
1956-1957	78,504	.0178	1,397
1957-1958	86,754	.0188	1,631
1958-1959	94,994	.0197	1,871
1959-1960	101,934	.0220	2,243
1960-1961	113,864	.0198	2,255
1961-1962	128,894	.0213	2,745
1962-1963	141,388	.0233	3,294
1963-1964	158,388	.0197	3,120
1964-1965	178,238	.0209	3,725
1965-1966	205,888	.0190	3,912
1966-1967	232,672	.0155	3,606
1967-1968	261,207	.0179	4,676
1968-1969	266,719	.0196	5,228
1969-1970	294,536	.0196	5,773
1970-1971	324,022	.0196	6,351
1971-1972	357,334	.0196	7,004
1972-1973	396,804	.0196	7,777
1973-1974	431,796	.0196	8,463
1974-1975	474,719	.0196	9,304
1975-1976	515,310	.0196	10,100
1976-1977	554,407	.0196	10,866
1977-1978	594,251	.0196	11,647
1978-1979	628,123	.0196	12,311
1979-1980	663,814	.0196	13,011
1980-1981	692,601	.0196	13,575

Just as there are no enrolment data on students in physics, there are no data on bachelor's degrees granted in physics.

To overcome this lack, it is assumed that the graduating ratio in physics is the same as that in pure sciences - pure sciences are utilized as this is the closest breakdown including physics for which there is degree data.

To obtain undergraduate physics degrees utilizing the graduating ratio in pure sciences involves first the determination of those physics

students who were undergraduates. To obtain the latter, it is necessary to subtract master's and doctoral students from the previous totals. The method of projecting master's and doctoral enrolments will be outlined later. Table 3.2 below presents undergraduate enrolments in physics to 1968 with projections to 1976.

Table 3.2

Undergraduate Enrolment in Physics

Year	Undergraduate Enrolments in Physics
1954-1955	1,118
1955-1956	1,210
1956-1957	1,189
1957-1958	1,399
1958-1959	1,608
1959-1960	1,920
1960-1961	1,826
1961-1962	2,336
1962-1963	2,827
1963-1964	2,576
1964-1965	3,097
1965-1966	3,112
1966-1967	2,704
1967-1968	3,664
1968-1969	4,128
1969-1970	4,538
1970-1971	4,973
1971-1972	5,466
1972-1973	6,048
1973-1974	6,564
1974-1975	7,198
1975-1976	7,897

The graduation ratio in pure sciences is obtained by expressing degrees granted in any one year as a ratio of the average of the current enrolment plus the enrolment of the three previous years. This ratio was applied in each year from 1957 to 1968 to the undergraduate enrolment in physics and then the projected value of the ratio was applied to the projected undergraduate enrolment to 1976. The following time series gives the final results.

Table 3.3

Bachelor's Degrees in Physics

Year	Bachelor's Degrees in Physics
1957-1958	403
1958-1959	440
1959-1960	495
1960-1961	479
1961-1962	569
1962-1963	656
1963-1964	611
1964-1965	703
1965-1966	706
1966-1967	634
1967-1968	804
1968-1969	886
1969-1970	958
1970-1971	1,035
1971-1972	1,122
1972-1973	1,225
1973-1974	1,316
1974-1975	1,428
1975-1976	1,552

The above figures are adjusted later for those going on to graduate work.

3.3(c) Master's Degrees

(i) Main Subfields

Data comparability represented the greatest difficulty when attempting a projection of the number of master's degrees entering the labour market.

To obtain a degree projection, it was first necessary to obtain an enrolment projection.

The following table presents historical masters enrolment to 1968 along with the projected enrolment to 1978 (the extra two years are necessary for later calculations), which was obtained by regressing master's enrolments on total physics students.

Table 3.4

Master's Enrolments in Physics
Main Subfields

Year	Master's Enrolments in Physics Main Subfields
1961-1962	117
1962-1963	104
1963-1964	115
1964-1965	139
1965-1966	143
1966-1967	166
1967-1968	175
1968-1969	199
1969-1970	217
1970-1971	236
1971-1972	258
1972-1973	284
1973-1974	307
1974-1975	335
1975-1976	362
1976-1977	388
1977-1978	414

The master's degrees projection was obtained by regressing master's degrees from 1957 to 1968 on the average of the current year plus the previous years enrolment.

The historical data for the years 1958-1959 to 1967-1968 are presented in Table 3.5 along with the projections to 1977-1978.

Table 3.5

Master's Degrees in Physics
Main Subfields

Year	Master's Degrees in Physics Main Subfields
1958-1959	71
1959-1960	72
1960-1961	98
1961-1962	117
1962-1963	104
1963-1964	115
1964-1965	139
1965-1966	143
1966-1967	166
1967-1968	175
1968-1969	199
1969-1970	217
1970-1971	236
1971-1972	258
1972-1973	284
1973-1974	307
1974-1975	335
1975-1976	362
1976-1977	388
1977-1978	414

(ii) Allied Subfields

Exactly the same methods used to project master's enrolment and degrees in the main subfields were used for the allied subfields. From DBS sources, it was possible to isolate enrolment in all of the allied subfields except for numerical methods and computations and maths of resource use. Since these fields accounted for 46 per cent of the stock according to the 1967 survey, the DBS data on enrolments was increased by 46 per cent. Also, since it was impossible to obtain accurate data on degrees, the same graduation ratio obtained for the main subfields was applied to the allied subfields. The results are presented in Table 3.6 - the projections being from 1969 on.

Table 3.6

Master's Enrolment and Degrees in
Physics - Allied Subfields

Year	Master's Enrolment in Physics Allied Subfields	Master's Degrees in Physics Allied Subfields
1961-1962	171	96
1962-1963	255	120
1963-1964	291	130
1964-1965	330	141
1965-1966	353	148
1966-1967	487	186
1967-1968	552	204
1968-1969	651	232
1969-1970	751	261
1970-1971	857	291
1971-1972	977	325
1972-1973	1,119	366
1973-1974	1,245	402
1974-1975	1,399	446
1975-1976	1,546	488
1976-1977	1,686	527
1977-1978	1,830	568
1978-1979	1,952	603
1979-1980	2,080	640
1980-1981	2,184	669

The master's graduates entering doctoral study will be subtracted later.

3.3(d) Doctoral Degrees

Similar computations as for the master's were applied to obtain the doctoral results. These results are presented in Table 3.7.

Table 3.7

Doctoral Enrolments and Degrees - Main Allied Subfields

Year	Doctoral Enrolments in Physics Main Subfields	Doctoral Enrolments in Physics Allied Subfields	Doctoral Degrees in Physics Main Subfields	Doctoral Degrees in Physics Allied Subfields
1961-1962	192	230	27	48
1962-1963	245	323	59	66
1963-1964	279	367	50	74
1964-1965	315	431	61	87
1965-1966	420	500	58	101
1966-1967	462	585	71	117
1967-1968	532	701	105	140
1968-1969	568	838	114	167
1969-1970	639	967	128	192
1970-1971	714	1,104	142	219
1971-1972	798	1,259	159	249
1972-1973	898	1,442	179	285
1973-1974	987	1,605	196	317
1974-1975	1,095	1,804	217	356
1975-1976	1,198	1,993	237	393
1976-1977	1,297	2,174	257	429
1977-1978	1,398	2,359	277	465
1978-1979	1,484	2,516	294	496
1979-1980	1,575	2,682	311	528
1980-1981	1,648	2,816	326	555

[illegible] Total Labour Market Supply from Educational Institutions

(i) Bachelor's Degrees Entering Labour Market

In order to ascertain the number of entrants from universities entering the labour market each year, it is necessary to subtract from total bachelor's degrees those going into masters work and those going directly into doctoral work. To arrive at this result, it is assumed that all master's and doctoral students in both the main and allied subfields of physics received a bachelors degree in physics. This is not an assumption which should bias the results to any great extent as earlier undergraduate enrolment in physics was obtained by subtracting only graduate students in the main subfields from the total number of physics students. To some extent, these two extreme assumptions should be offsetting.

According to Physics in Canada, approximately 50 per cent of the students at the masters level are immigrants. It is assumed, then, that 50 per cent of the master's students received their bachelor's degrees from Canadian universities. It is assumed that an undergraduate receiving his degree in time "t" will receive his masters degree one year later - he will then be placed on the labour market after this time.

Also, there are some who enter a doctoral program immediately upon completion of undergraduate studies. According to National Research Council publications, approximately 33 per cent of students enrolled for a doctorate in the physical sciences have only a bachelors degree, but approximately 23 per cent of doctoral students are immigrants and therefore this group did not obtain their bachelor's degrees from Canadian universities. It is assumed that an undergraduate receiving his degree in time "t" will receive his doctoral degree in time "t + 4" - he will be placed on the labour market at this time.

(ii) Master's Degrees Entering Labour Market

According to National Research Council publications, approximately 67 per cent of the graduate students enrolled for a doctorate in physical sciences at Canadian universities for the year 1967-1968 had master's degrees. It is assumed that all immigrant doctoral students received their master's degrees in Canada. It is assumed that a graduate student receiving his masters degree in time "t" will receive his doctoral degree three year later - he will then be placed on the labour market at this time. All other master's degrees are placed on the labour market in their year of graduation.

(iii) Doctorates Entering Labour Market

It is assumed that all persons receiving doctorates enter the labour market and thus those going on for post-doctoral work are considered to be on the labour market. Those persons entering a doctoral program but do not complete it have already been put on the labour market.

(iv) Total Degrees Entering Labour Market

This section presents in tabular form the results of the calculations outlined in Section 3.2(3), (i)-(iii).

Table 3.8

Degrees in Physics Entering the Labour Market

Year	Bachelor's Degrees	Master's Degrees Main Subfields	Master's Degrees Allied Subfields	Doctoral Degrees Main Subfields	Doctoral Degrees Allied Subfields	Total
1961-1962	417	84	46	27	48	622
1962-1963	466	63	62	59	66	716
1963-1964	410	76	62	50	74	672
1964-1965	488	91	63	61	87	790
1965-1966	450	73	54	58	101	736
1966-1967	354	90	74	71	117	706
1967-1968	486	89	75	105	140	895
1968-1969	531	104	85	114	167	1,001
1969-1970	567	110	94	128	192	1,091
1970-1971	599	116	100	142	219	1,176
1971-1972	640	127	113	159	249	1,288
1972-1973	699	139	127	179	285	1,429
1973-1974	741	148	139	196	317	1,541
1974-1975	806	163	158	217	356	1,700
1975-1976	885	176	176	237	393	1,867

It is important to note that the above table represents potential supply in that it does not take account of deaths, retirements, net migration and persons who enter physics from other fields or physicists who leave physics from other fields. These items will be evaluated in the following sections.

3.4 Net Migration

Total immigration data is available but emigration data is only available on those physicists who went to the U.S.A. The immigration and emigration and net migration data is presented in Table 3.9 The projection being from 1969 on.

Table 3.9

Immigration, Emigration and
Net Migration of Physicists

Year	Immigration	Emigration	Net Migration
	(1)	(2)	(3) = (1) - (2)
1962	36	29	7
1963	28	35	-7
1964	56	29	27
1965	108	23	85
1966	156	48	108
1967	183	46	137
1968	184	66	118
1969			168
1970			193
1971			218
1972			243
1973			268
1974			294
1975			319
1976			344

3.5 Reduction Factor

It is not possible to obtain direct data on deaths, retirements and net occupational mobility of physicists. It is possible, however, to construct the theoretical potential stock and to subtract from it the actually observed stock to determine the loss from the profession. This loss or reduction factor can be expressed as a per cent of the theoretical stock and be utilized in order to make appropriate supply adjustments.

The procedure used to compute the reduction factor is as follows:

(1) Add to the total of active physicists in year "t", the Canadian graduates and net immigration from year "t + 1" to obtain the theoretical total for year "t + 1".
(2) Subtract from the theoretical total for time "t + 1", the actual total in time "t + 1".
(3) Express the difference obtained from (2) as a percentage of the theoretical total of time "t + 1" - this is the reduction factor for time "t + 1".

As the actual stock of physicists has been set for the years 1961 through 1966 - it is possible to obtain estimates of the theoretical stock of physicists for these years. The reduction factors for those years are presented in Table 3.10.

Table 3.10

Reduction Factor

Year	Reduction Factor
1961-1962	.26
1962-1963	.22
1963-1964	.21
1964-1965	.24
1965-1966	.22

No significantly discernible trend is evident from the above series. Because of a possible slight trend a value of .23 - .01 greater than the average value of the series was selected.

Application of the reduction factor of .23 to the projected theoretical totals yields the projected actual totals as presented in Table 3.11 below.

Table 3.11

Projected Actual Stock
of Physicists

Year	Number of Physicists
1967	2,574
1968	2,762
1969	3,027
1970	3,320
1971	3,630
1972	3,974
1973	4,367
1974	4,776
1975	5,232
1976	5,731

The reduction factor was not applied on a main field allied subfield basis as the bachelor's graduates and the net migrants cannot be identified by main and allied subfields.

The reconciliation and implications of the supply and requirements projections are taken up in Chapter 4.

CHAPTER 4

IMPLICATIONS OF SUPPLY AND REQUIREMENTS PROJECTIONS

4.1 Supply-Requirements Differential

The total projected requirements for physicists obtained in Chapter 2 was 4,613 The projected requirements are 1,118 less than the projected supply of 5,731 physicists obtained in Chapter 3. As a percentage of projected requirements, the excess supply is approximately 25 per cent.

4.2 Implications of Excess Supply

It would be extremely unrealistic to assume that all or even a major proportion of the excess supply will be unemployed. It would be realistic though to assume that many physicists will be underemployed in the sense that a certain degree level will not command the level of work in 1976 as it does today. It again would be unwise to assume that the bachelor's and some of the master's graduates will be among the unemployed or underemployed while the doctoral graduate will be traditionally employed. With the vagaries of the direction of research (pure versus applied) and employer preferences in general, it could turn out that the doctoral graduates will be the most adversely affected segment in the face of excess supply. The most realistic expectation is that difficulties will be experienced although probably not equally at all levels.

The projected final demand was nearly evenly split between the main and allied subfields and the supply disregarding the unknown bachelors breakdown is approximately the same at the masters-doctors level so there is no reason to predict more softness in the allied versus the main field labour market and vice versa.

Generally speaking, the market for physicists will not be buoyant in the next five years if the demand for physicists continues at its historically observed pace and if student's enrolments continue as in the past.

4.3 Policy Considerations

There are two obvious ways to deal with an over-supply situation: (1) restrict immigration, (2) curb enrolments.

The immigration projections indicate that some perceptible change could be achieved as the net migration was approximately 13 per cent of total domestic output in 1968 and is projected to rise to approximately 18 per cent in 1976. It must always be borne in mind, however, that non-economic considerations also have their place in the evaluation of immigration policies.

Restrictions on enrolment can obviously change the market situation. If such a policy were to be entertained, it would be wise to bear in mind that restriction at the undergraduate level has the most far reaching implications as undergraduate education is socially approached on a universal accessability criterion and too much restriction automatically leads to fewer potential graduate students. If the market situation were to change significantly on the demand side in the next few years, we might easily find ourselves with a shortage of potential graduate students. With the above in mind, paring might be more wisely considered at the graduate level where the investment costs are considerably larger and the social implications are less far reaching.

Alterations on the demand side could also be considered, i.e., greater government participation in research, etc. If the purpose of such policies is simply to employ people without any reasonably certain expectation of results which will be of benefit to economic growth in the future, the policies could simply serve to aggravate the situation in the future.

SELECTED REFERENCES

Bulletin of The Canadian Association of Physicists. Physics in Canada, Volume 21, No. 3, Special Issue. Toronto: University of Toronto Press, 1965.

------. Immigration Branch. Immigration Statistics. Ottawa: Queen's Printer, 1963 to 1965.

Canada. Department of Citizenship and Immigration. Statistics Section. Immigration Statistics. Ottawa: Queen's Printer, 1960 to 1962.

Canada. Department of Labour. Economics and Research Branch. 1962 Survey of Employment and Requirements, Engineering and Scientific Manpower. Ottawa: Queen's Printer, 1962.

Canada. Department of Manpower and Immigration. Canada Immigration Division. Immigration Statistics. Ottawa: Queen's Printer, 1966 to 1967.

Canada. Department of Manpower and Immigration. Program Development Service, Research Branch. A Projection of Manpower Requirements by Occupation in 1975, by B. Ahamad. Ottawa: Queen's Printer, 1969.

------. Canada's Highly Qualified Manpower Resources, by A. G. Atkinson, K. J. Barnes and Ellen Richardson. Ottawa: Queen's Printer, 1970.

Canada. Dominion Bureau of Statistics. Aggregate Productivity Trends. Cat. No. 14-201, 1946-1967.

------. Canadian Statistical Review. Cat. No. 11-003, various issues.

------. 1961 Census of Canada.

------. Federal Government Expenditures on Scientific Activities. Cat. No. 13-401, various issues.

------. Industrial Research Development Expenditures. Cat. No. 13-509, 1957.

------. Industrial Research Development Expenditures. Cat. No. 13-516, 1959.

------. Industrial Research Development Expenditure in Canada. Cat. No. 13-520, 1961.

------. Industrial Research and Development Expenditures in Canada. Cat. No. 13-524, 1963.

------. Industrial Research and Development Expenditures in Canada. Cat. No. 13-527, 1965.

------. National Accounts, Income and Expenditure. Cat. No. 13-201, various issues.

------. Salaries and Qualifications of Teachers in Universities and Colleges. Cat. No. 81-203, various issues.

------. Survey of Education Finance. Cat. No. 81-208, various issues.

------. Survey of Higher Education, Part I: Fall Enrolment in Universities and Colleges. Cat. No. 81-204, various editions.

------. Survey of Higher Education, Part II: Staff, and Summary. Cat. No. 81-211, various issues.

------. Weekly Bulletin. Cat. No. 11-002, various issues.

Canada. Scientific Research and Development. Prepared for the Royal Commission on Government Organization, Report No. 23. Ottawa: Queen's Printer, 1963.

Institute of International Education. Open Doors. New York: various issues.

U.S.A. Department of Justice. Annual Report of the Immigration and Naturalization Service. Various issues.

Zsigmond, Z.E. and C.J. Wenaas. Enrolment in Educational Institutions by Province 1951-52 to 1980-81. Prepared for the Economic Council of Canada, Staff Study No. 25. Ottawa: Queen's Printer, 1970.